TECHNICAL REPORT, **LEVEL**

# MORPHOLOGICAL CHARACTERISTICS OF NORTH ATLANTIC AND NORTH PACIFIC SEAMOUNTS AS FACTORS FOR DESIGNING EFFECTIVE SURVEY DETECTION STRATEGIES.

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DEWEY R. BRACEY

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report defines bathymetric and geophysical survey strategies, based on seamount morphological parameters, for the detection of North Atlantic and North Pacific seamounts. Characteristics derived from the morphological data are used to develop required survey track orientations and track spacing to maximize seamount encounter probability in these oceans using the most economical survey pattern.

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## INTRODUCTION

To develop an effective search technique, one must first have as clear an understanding as possible of the object of the search. This report attempts to define seamount morphological characteristics (size, shape, orientation) in the North Atlantic and North Pacific Oceans. The factors resulting from this definition can then be used for the development of efficient bathymetric or geophysical survey strategies to locate and delineate those seamounts which may constitute navigational hazards or that may be of interest to other Navy programs.

A resultant corollary is that those areas that have sufficient survey coverage within accepted probability limits can be quickly identified and excluded from further survey effort, while those areas with limited coverage can be filled in with the required track spacing for adequate delineation of any existing seamount.

# I.   NORTH ATLANTIC SEAMOUNTS

Appendix A presents morphological data for 72 isolated seamounts, randomly selected from the Bathymetric Atlas of the North Atlantic (C), (1975), at depths equal to or greater than 2000 meters.  These data reveal that the seamounts can be divided into two morphological classes:  1) Elongated, oval-shaped seamounts (64%); and 2) conical seamounts (35%).

Figure 1 shows the basal axial dimension distribution of the seamounts. The distribution, while random, is not normal but seems to follow a chi-square of F distribution pattern.  A possible explanation is that while there is a minimum basal dimension size, the maximum basal dimension can increase without limit.

Also shown on this figure are the basal dimensions of those seamounts less than or equal to 1000 meters in depth, the seamounts of particular interest in this study.

Figure 2 is a plot of short versus long axial dimensions.  The mean and standard deviations of the seamount dimensions are also plotted; they are 16.8 x 23.5 nm and $\pm$ 6.0 x $\pm$ 8.5 nm, respectively.

The linear regression line for the elongated seamounts is also shown in figure 2.  The line is determined by $A_S = 0.56A_L + 1.53$, where $A_S$ and $A_L$ are the short and long axial dimensions in nm, respectively.  The line indicates that the long axis of the average elongated seamount is about 1.5 times the short axis dimension.  Statistical evidence indicates that the elongation is significant at the 95% confidence level.

As shown in Appendix A, the long axes of the elongated seamounts tend to parallel the direction of sea-floor spreading.  Fifty-seven percent of the elongated axes fall within $\pm$ 30° of the sea-floor spreading direction, while 80% fall within $\pm$ 45° of this azimuth.  Two possible explanations for this

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# North Atlantic Seamounts
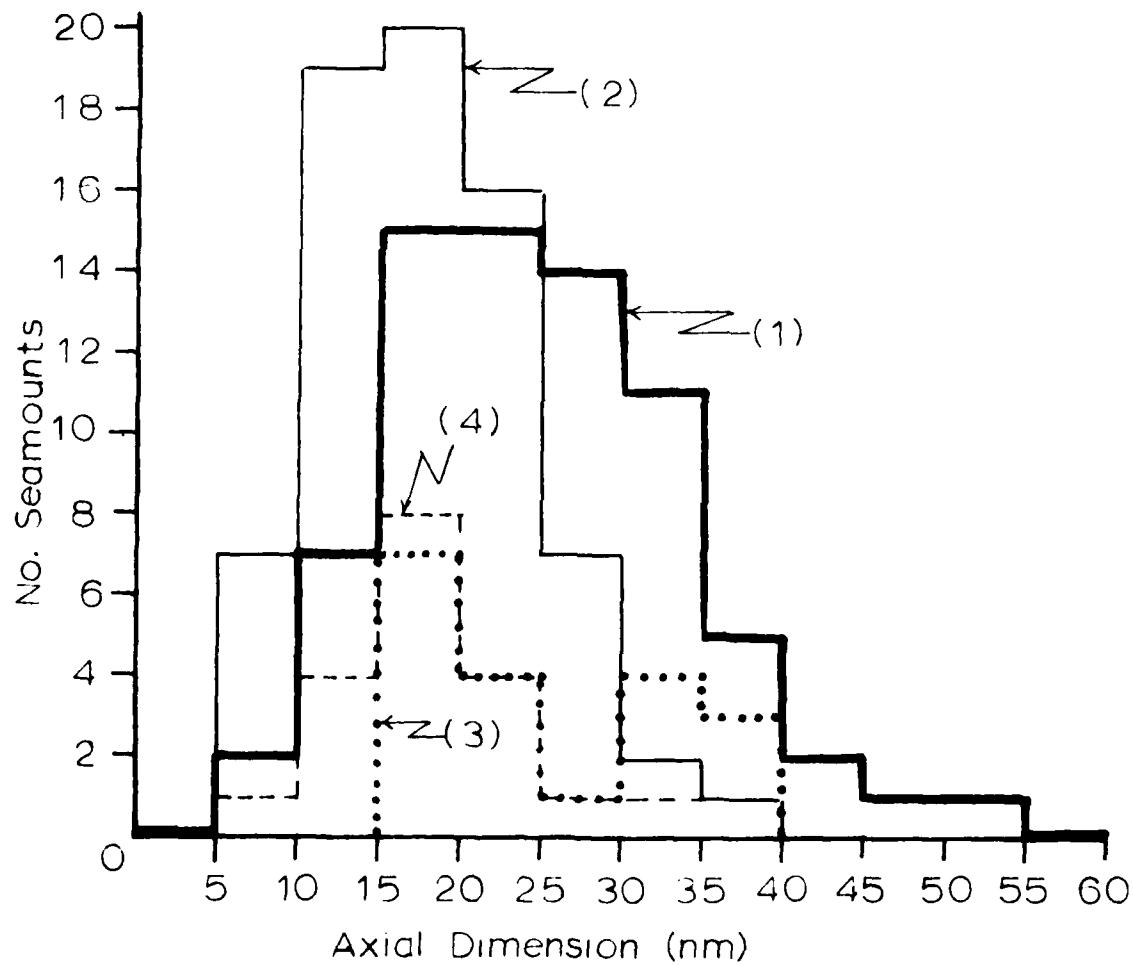


Figure 1. Histograms of North Atlantic seamount basal dimension distributions. Histogram (1) shows long axis distributions, (2) shows short axis distributions, and (3) and (4) show the same respective data for seamounts with peaks ≤ 1000 m in depth. Conical seamount are in-cluded in the distributions.
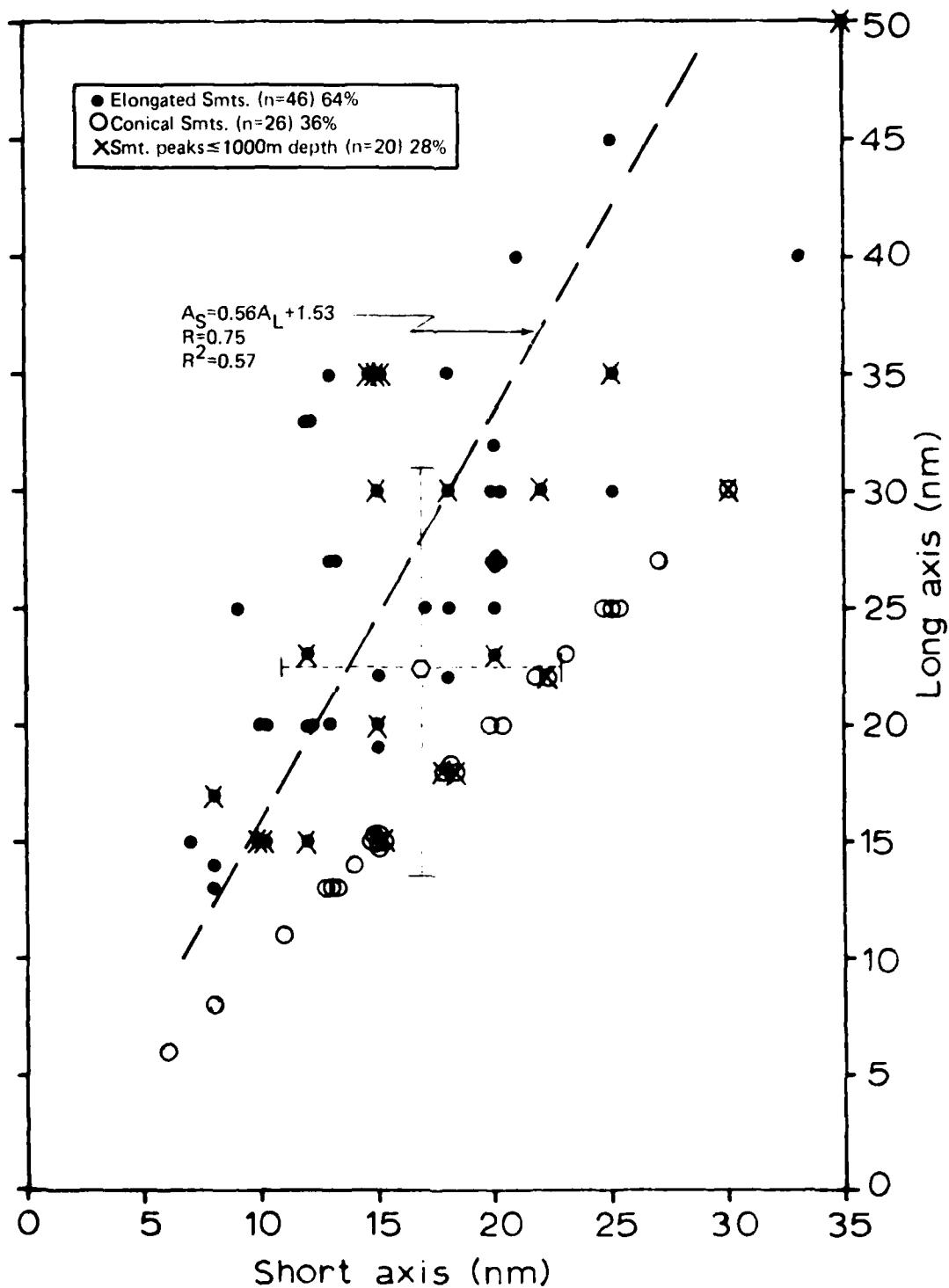
Figure 2. North Atlantic seamount short vs. long axis basal dimension plot. Mean dimension and standard deviations for all seamounts indicated by hexagon and light dashed lines, respectively. Linear regression line for elongated seamounts shown by heavy dashed line. $R^2$ and R are goodness of fit and correlation coefficient, respectively.

phenomenom are offered:  1)  the source of the seamount-forming magma may have been stationary in the upper mantle beneath the moving oceanic crust, depositing the magma pile on progressively younger crust and elongating the seamount in the spreading direction; 2)  the magma source may have been located in the oceanic crust which was moving outward and downward (due to crustal cooling and shrinkage) from the spreading axis, resulting in the out-pouring magma to tend to flow "downhill" under the influence of gravity, resulting in elongation of the seamount in the spreading direction.

Figure 3 shows that the height of the average North Atlantic seamount is 2378 $\pm$ 872 (s.d.) meters and that the seamount occurs in water depths of 4092 $\pm$ 772 (s.d.) meters.  Statistical tests show  that there is no signifi-cant linear regression (increase in height with depth) for either all the seamounts considered together or for the conical seamounts alone.  There is significant regression for those seamounts $\leq$ 1000 meters in depth, as shown in figure 3; but this is simply a mathematical expression of the obvious-- in order to reach within 1000 meters of the surface, heights would have to increase with depth.

In the ocean basins, crustal depths are also a function of age (Sclater, and others, 1971).  The approximate age taken from their age versus depth plot for the North Atlantic is shown as one of the ordinates in figure 3. This must be considered as only a rough estimate of age due to the uncer-tainties involved but may prove useful in areas where crustal ages have been established by magnetic anomaly identifications.

One interesting feature of figure 3 is that there appear to be no sea-mounts in water depths between 2200 and 3000 meters ($\sim$ 2-5 m.y. B.P.).  This may, however, result from the sampling technique and should be regarded with caution.
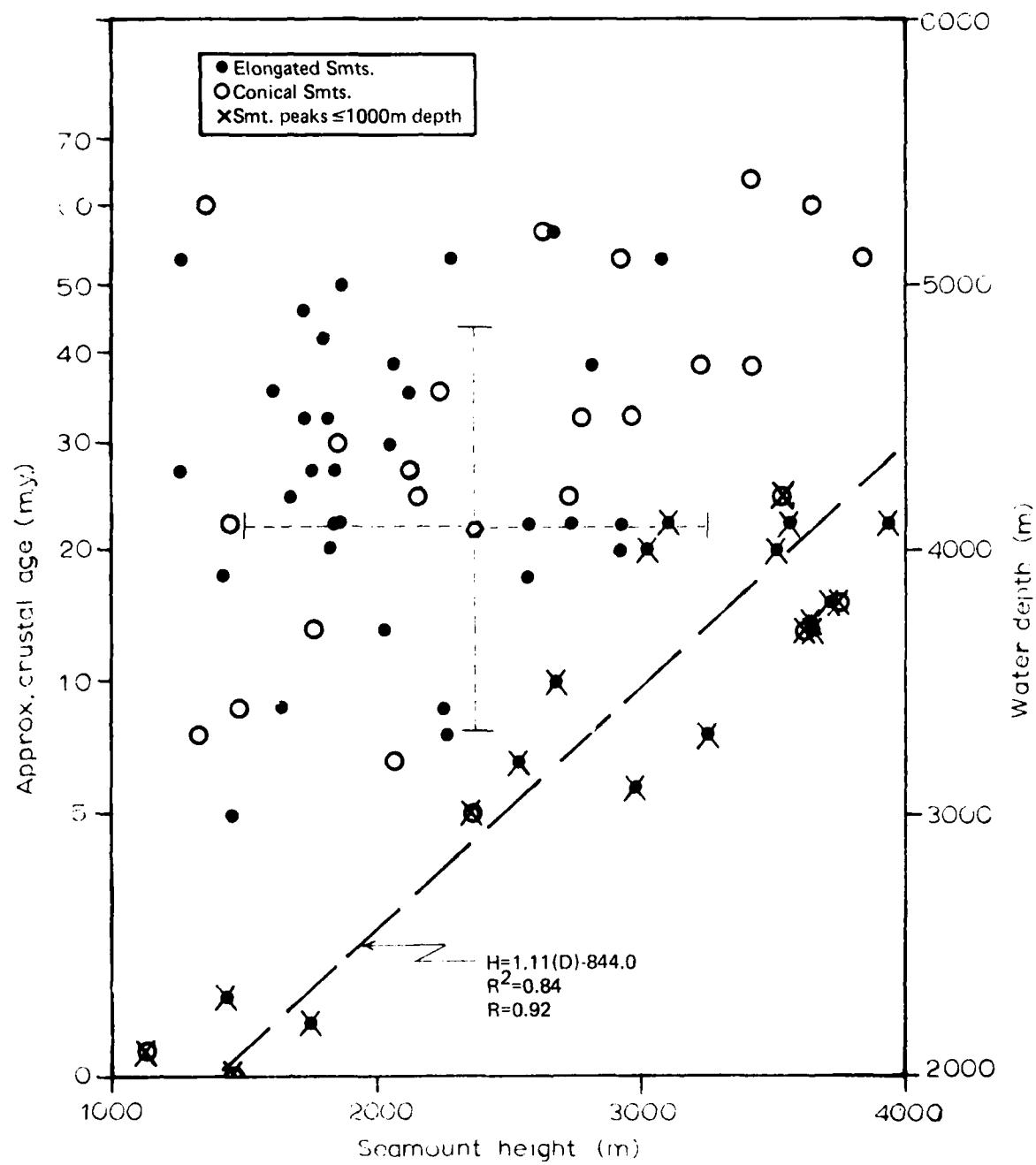
Figure 3. Seamount height vs. water depth and crustal age in the North Atlantic. Mean height/depth and standard deviations shown by hexagon and light dashed lines, respectively. Linear regression line for seamount peaks ≤ 1000 m depth shown by heavy dashed line. $R^2$ and R as in figure 2.

Another interesting feature is the total absence of seamounts shoaler than 1000 meters in water depths greater than 4100 meters ($\sim 2\,5$ m.y. B.P. age). It is doubtful that this phenomenon is also an artifact of the sampling technique since half the seamounts sampled were in water depths greater than 4100 meters.

The probability of encounter curves in figure 4 were developed by an empirical technique from the data of figure 1. The method consists of first normalizing the interval areas (0-5 nm, 5-10 nm, etc.) of histograms (1) and (2) of figure 1. The probability that a seamount will be encountered by a survey track spacing with a given interval is then determined by:

$$P_n = 1 + \sum_{i=0}^{n} (-N_i)$$

where $i, \ldots, n$ are the intervals considered
(0-5, 5-10, 10-15, etc.)

N is the normalized value of the interval,

and Pn is the probability of encounter in n intervals.

Pn is then plotted at the median point of the interval considered. Note that "encounter" means passing over any part of the seamount.

This method has an advantage in that it assumes no particular distribution (normal, chi-square, etc.) of the data but uses the actual data distribution. It does assume that the data are randomly distributed. By inspection of figure 1, this assumption seems warranted.

The curves in figure 4 give the probability of encountering a North Atlantic seamount under two conditions: 1) The long axis of elongated seamounts is perpendicular to the track, and 2) the long axis is parallel to the track. For example: A 95% probability of encounter would require an 8.5 nm spacing in case 1) and a 5 nm spacing in case 2).

To summarize some of the factors resulting from this study which will bear upon seamount survey strategy in the North Atlantic:

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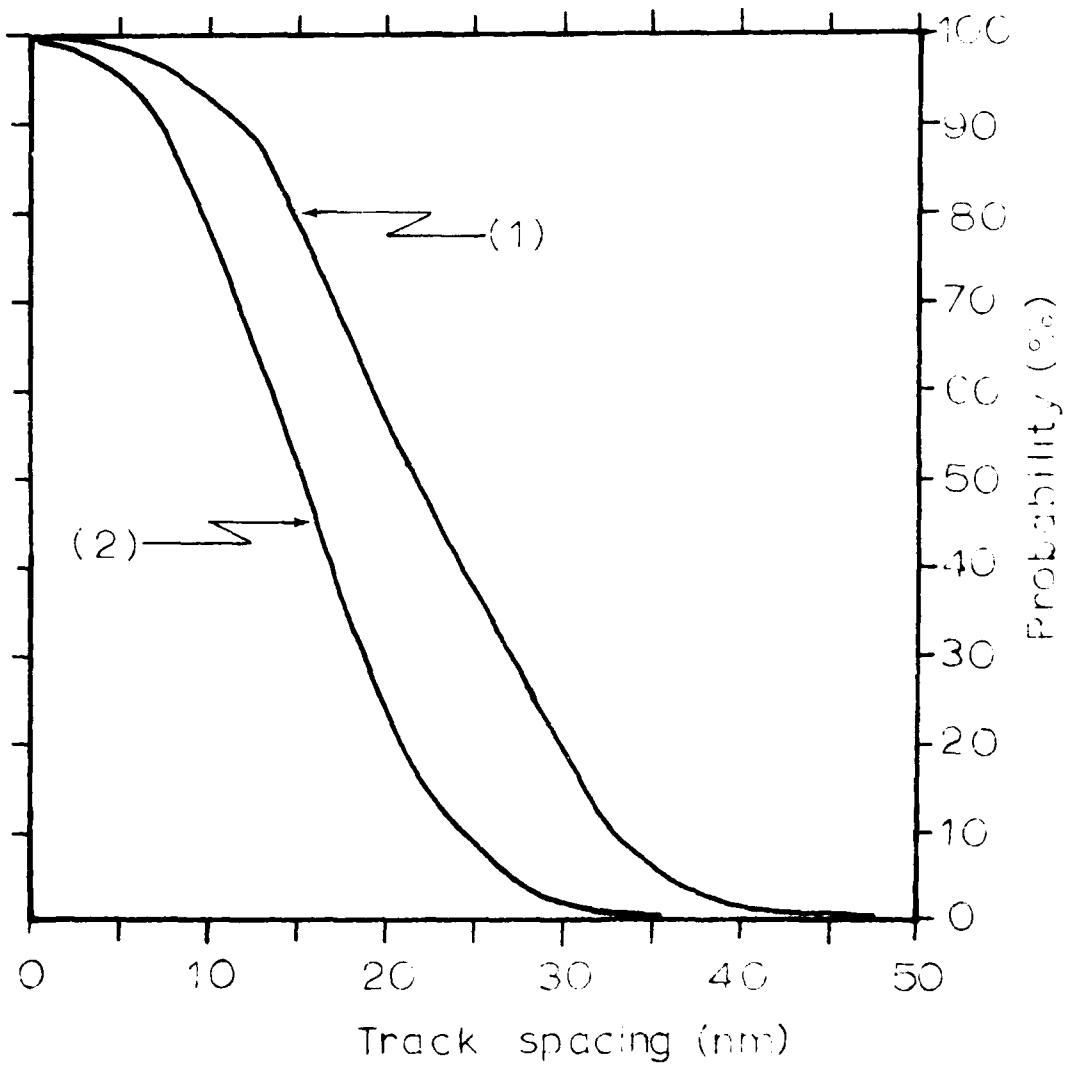
Figure 4. Percent probability (using empirical method) of encountering
a North Atlantic seamount with a given track spacing. Curve (1) assumes
that the long axis of elongated seamounts is normal to the track. Curve
(2) assumes that the short axis is normal to the track, and includes conical
seamounts.

1) Elongated seamounts are more prevalent in the North Atlantic than conical seamounts (65 versus 36).

2) The usual ratio of long to short axes of any elongated seamount is about 1.5:1.

3) The azimuths of the long axes of elongated seamounts tend to fall within $\pm$ 45° of the local sea-floor spreading direction; therefore, track orientation should be normal to this direction (parallel to the magnetic sea-floor spreading anomalies) to allow the maximum possible chance of encounter. These directions are quite well established in the North Atlantic, and the choice of track orientation should present no problem. An additional advantage is that the fracture zones, with their associated high-relief ridges and any associated seamounts, will also be normal to the track.

4) Since seamount peaks $\leq$ 1000 meters in depth seem to occur in water depths of less than 4100 meters, first priority should be given to surveys in these depths.

5) Maximum track spacing for 95 encounter probability in the North Atlantic is 5 nm if we assume the "worse case" configuration of the seamounts (all long axes parallel to the track); but as we have seen in 3), this will usually not be the case. We may therefore be justified in expanding this spacing somewhat (to about 6 nm) and still remain in the 95 confidence range.

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## II. NORTH PACIFIC SEAMOUNTS

Morphological data for the 100 North Pacific seamounts, selected by the same criteria as were those in the North Atlantic, are given in Appendix B. The data were extracted from the Bathymetric Atlas of the North Pacific Ocean (1973).

Figure 5 shows the distribution of the North Pacific seamount axial dimensions in 5 nm intervals as in figure 1. The long axis distribution [(1) in figure 5] is very unusual and unlike either the North Atlantic distributions or the Pacific short axes distribution. The reason for this anomalous distribution is not clear.

As in the Atlantic, elongated seamounts predominate over conical seamounts (74% to 26%). A cautionary note should be added here. Bathymetric data in the North Pacific are generally not as dense as those in the North Atlantic. Therefore, elongation of some seamounts may have resulted from cartographic license.

The plot of short versus long axial dimensions in figure 6 indicates that the mean North Pacific seamount is somewhat larger than its North Atlantic counterpart by about 2 - 3 nm. The mean basal dimensions are $19.1 \pm 6.4$ (s.d.) X $26.8 \pm 10.4$ (s.d.) nm. As in the North Atlantic, Pacific seamount long axial dimensions are approximately 1.5 times the short axis although the linear regression fit is not quite as good.

There is also a tendency here for the long axes of elongated seamounts to align themselves in the direction of sea-floor spreading. The data in Appendix B shows that 49% of the long axes fall within $\pm 30°$ of the spreading direction, while 66% fall within $\pm 45°$. While these percentages are less impressive than those in the Atlantic, there does seem to be significant

# North Pacific Seamounts
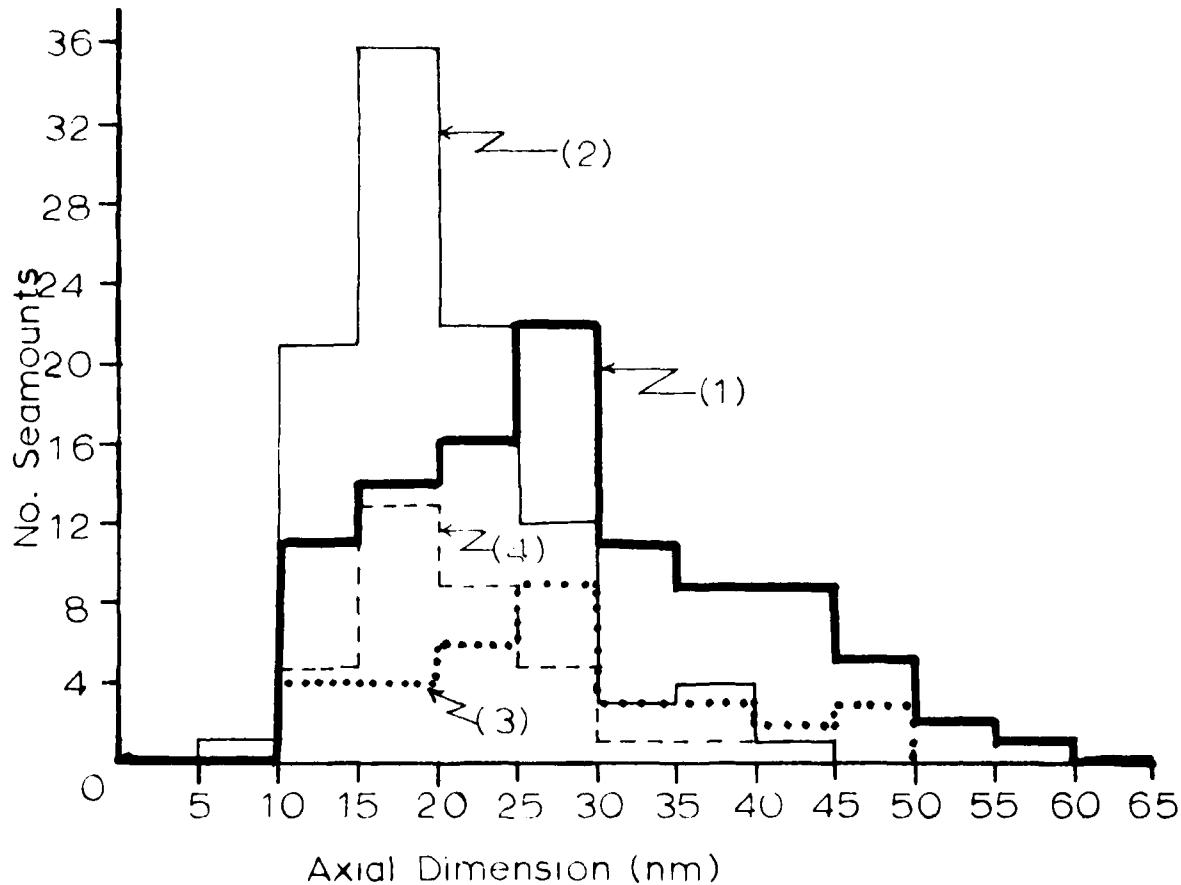


Figure 5. Histograms of North Pacific seamount basal dimension
distributions. Histogram (1) shows long axis distributions, (2)
shows short axis distributions, and (3) and (4) show the same respective
data for seamounts with peaks ≤ 1000 m in depth. Conical seamounts are
included in the distributions.
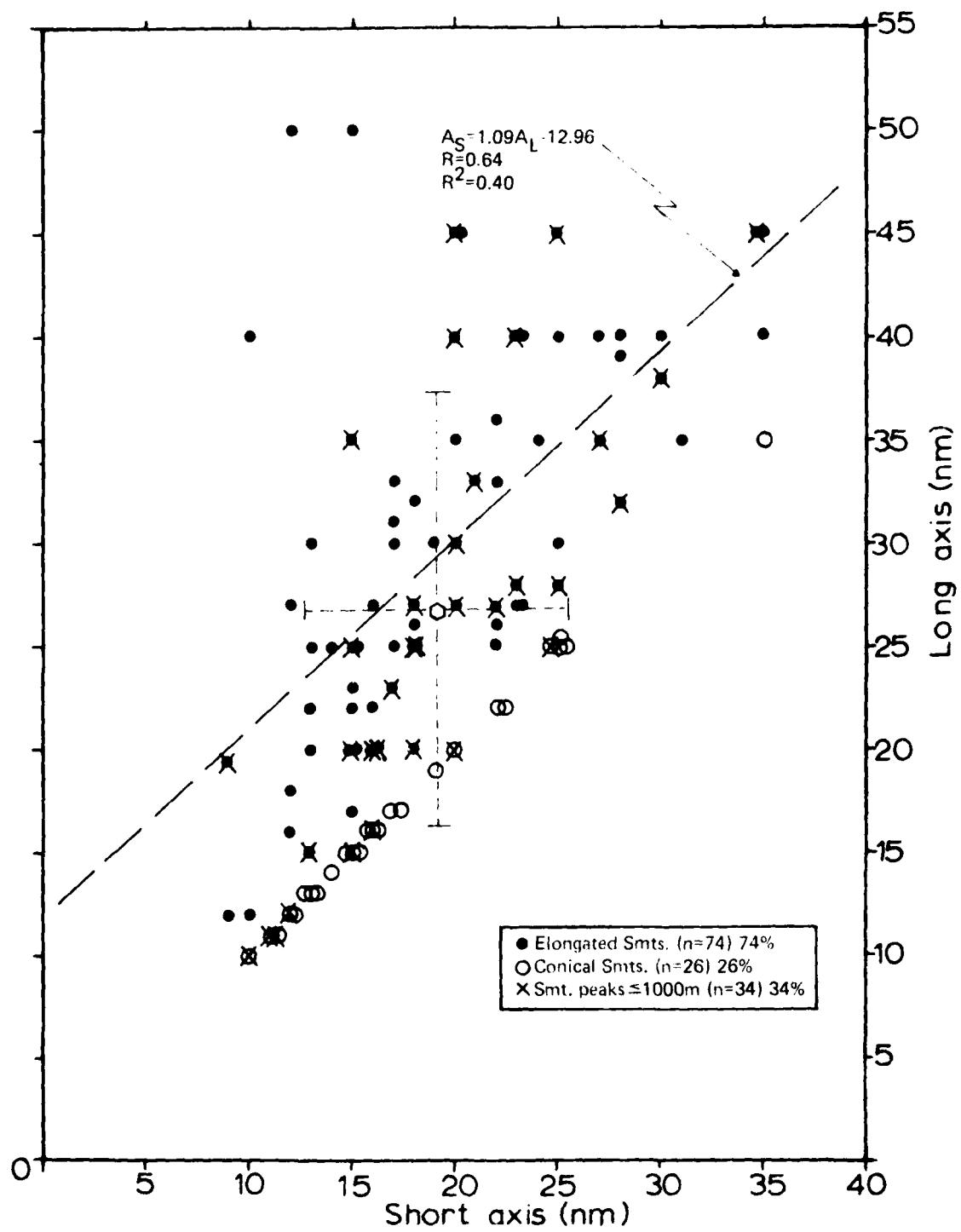
Figure 6. North Pacific seamount short vs. long axis basal dimension
plot. Mean dimension and standard deviations for all seamounts indicated
by hexagon and light dashed lines, respectively. Linear regression line
for elongated seamounts shown by heavy dashed line. $R^2$ and R as in
figure 2.

alignment of long axes in the spreading direction. The reasons for this
alignment may be similar to those given for the Atlantic in Section I.

Unlike North Atlantic seamounts, statistical tests show that the linear
regression plot of height versus depth for all the seamounts shown in figure
7 is real and significant at the 95% confidence level. It shows that there
is a definite increase in seamount height with water depth (age). The reason
for this phenomenon is not clear. Perhaps there has been a gradual decrease
in seamount activity with time or a reactivation of the older seamounts.

Figure 7 also shows that there is no "cutoff" depth (age) for seamounts
with peaks shoaler than 1000 meters as was the case in the North Atlantic
for depths exceeding 4100 meters. In the Pacific, shoal seamounts are found
to depths of 5700 meters.

The probability of encounter curves of figure 8 were computed by the
same method as those of figure 4 from the distribution data in figure 5.
The curves show that at the 95% confidence level, track spacings of 8.5 - 10.0
nm would be required for detection of North Pacific seamounts, depending on
whether the assumption was made that the long axes were parallel to the track
("worse case") or normal to the track orientation.

This increased track spacing for the North Pacific relative to the
North Atlantic can be attributed to the fact that the Pacific seamounts are
generally larger than their Atlantic counterparts.

Again, a summary of morphological factors relating to the design of
survey strategies to detect North Pacific seamounts is warranted:

1) As in the North Atlantic, elongated Pacific seamounts are more prevalent
than conical seamounts.

2) The usual ratio of North Pacific long to short axes is also about 1.5:1.

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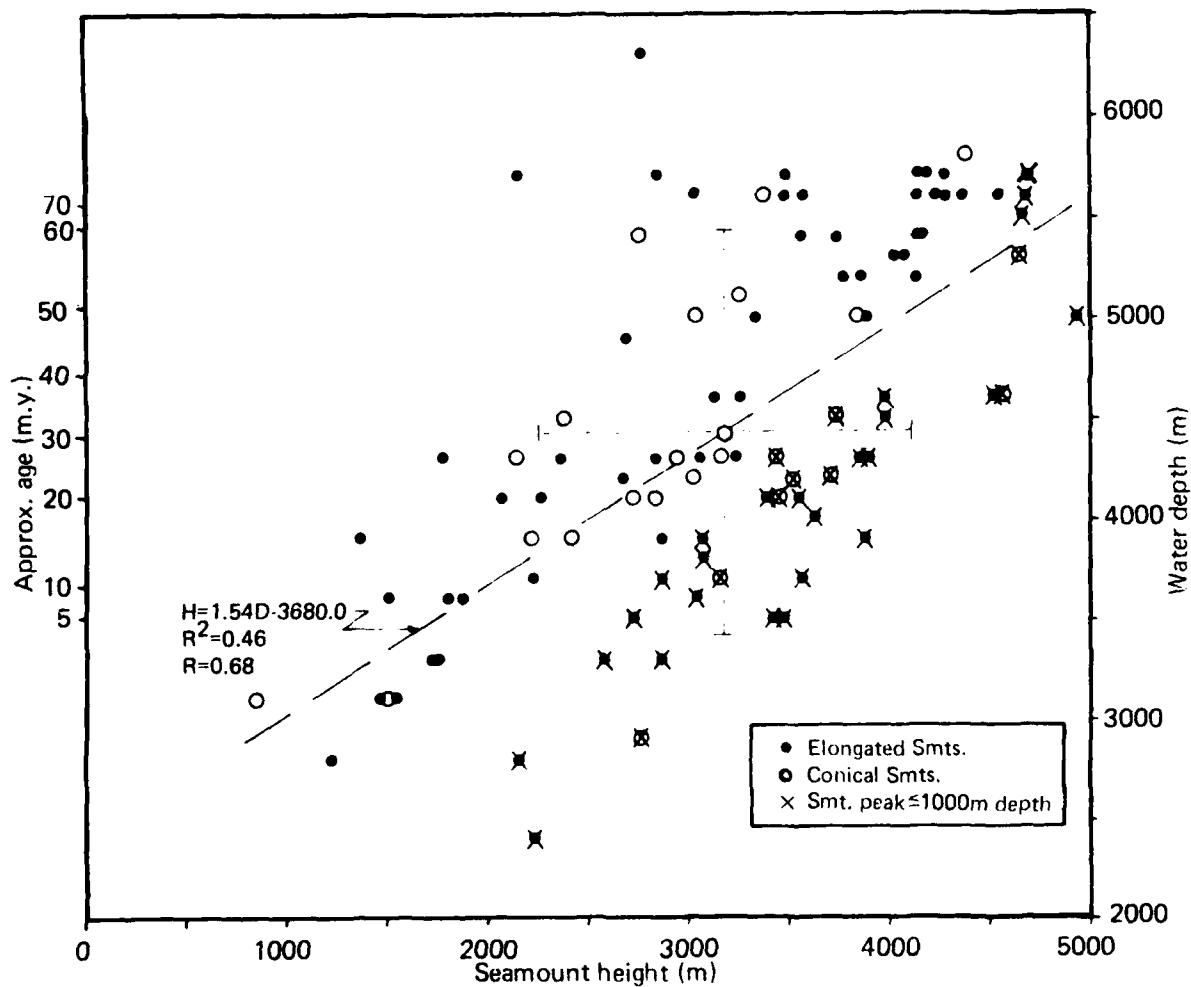
Figure 7. Seamount height vs. water depth and crustal age in the North Pacific. Mean height/depth and standard deviations shown by hexagon and light dashed lines, respectively. Linear regression line for all seamounts shown by heavy dashed line. $R^2$ and R as in figure 2.

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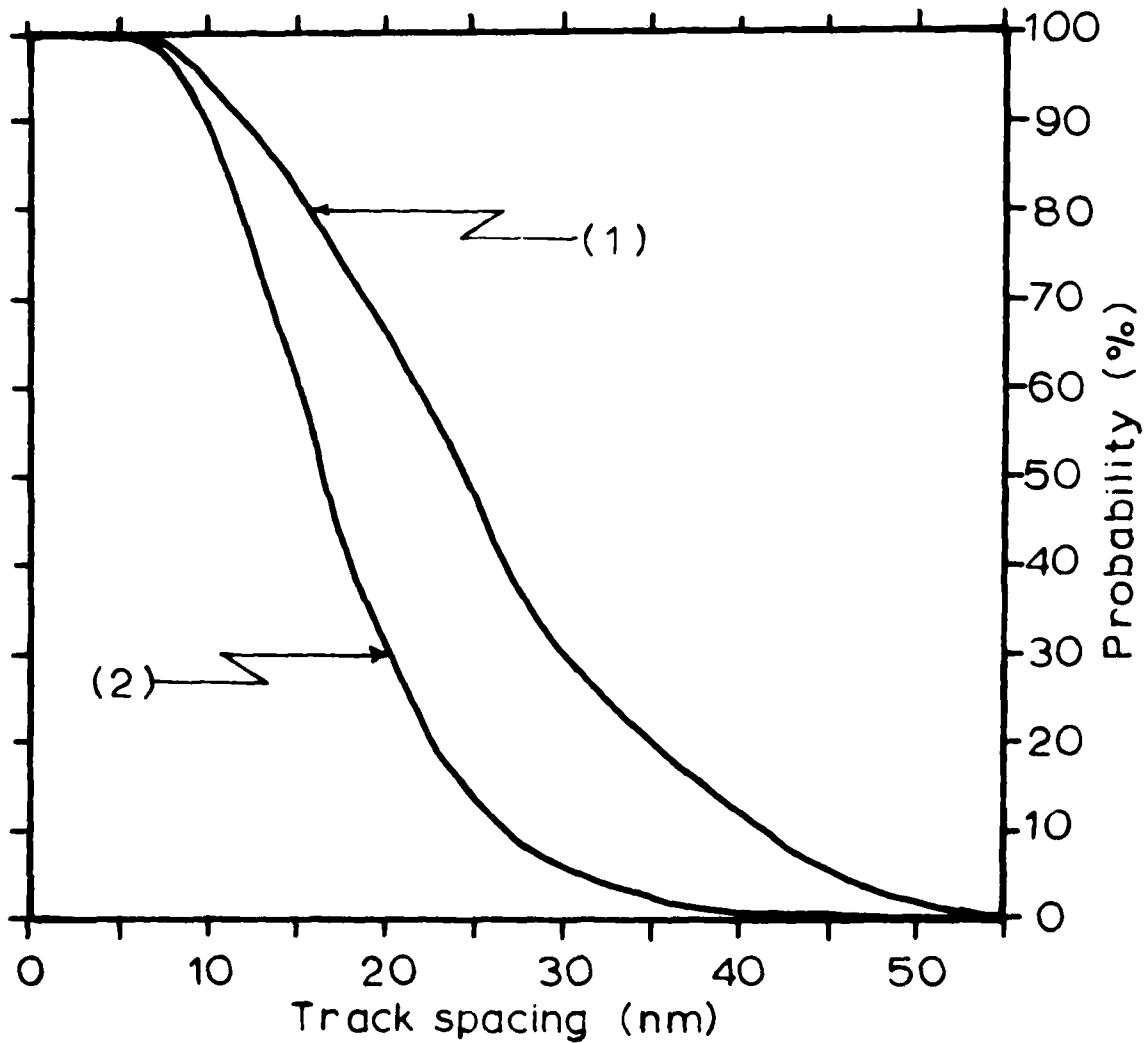
Figure 8. Percent probability (using empirical method) of encountering
a North Pacific Seamount with a given track spacing. Curve (1) assumes
that the long axis of elongated seamounts is normal to the track. Curve
(2) assumes that the short axis is normal to the track, and includes
conical seamounts.

3)  Azimuths of elongated North Pacific seamount long axes tend to parallel
the direction of sea-floor spreading.  Survey track orientation should
therefore be normal to this direction.  While not nearly as well established
as those in the North Atlantic, sea-floor spreading directions are known in
the Pacific to a degree that will allow proper track orientation.  The remarks
made in the summary of Section I as to fracture zone orientations also apply
here.

4)  There are no indications here of a decrease in the number of shoal sea-
mounts with depth/age--quite the contrary.  There is, therefore, no reason
to assign areal priorities on that basis.

5)  The maximum track spacing in the North Pacific under "worse case" condi-
tions is 8.5 nm.  However, there may be some justification for expanding this
somewhat ($\sim$ 9 nm) based on the knowledge of a preferred orientation of sea-
mount long axes normal to track.  Also, the observed increase in seamount size
with age/depth may allow an expansion of the track spacing in the older/deeper
areas of the North Pacific.

III.  LIMITATIONS AND CONCLUSIONS

As noted earlier, the probability of encounter courves of figures 4 and
8 are predicated upon passing over any part of a given seamount.  If seamounts
were perfect and regular conic structures, resting on perfectly flat ocean
floor, the track spacings given for various probabilities of encounter would
be sufficient to positively identify any feature encountered (bathymetric or
geophysical) as a seamount.  Unfortunately, seamounts are neither perfect
cones nor, in most cases, do they rest on perfectly flat ocean floor.  The
seafloor may contain features (knolls, etc.) that are indistinguishable from
a flanking seamount profile.  A "worse case" situation is selected to illus-
trate this point.

Figure 9 shows, in plan (A) and profile (B), the smallest (in basal
dimensions) North Pacific seamout lying within 1000 meters of the surface.
The plan view (A) shows the 8.5 nm track spacing specified for North Pacific
seamounts at the 95% probability of encounter for long axis parallel to
track, plotted at the worst possible encounter configuration (minimum relief
encounter).  If the seamount were a cone as shown in (B)-(1), the bathymetric
profile would show 850 meters maximum relief (and geophysical profiles would
show commensurate displacements); and there should be no problem in identify-
ing the feature as a seamount flank.  If, however, the seamount profile was
as (B)-(2), which is probably a more realistic gradient (there is no single
representative gradient known to this author which holds for all seamounts)
for at least the deeper part of the seamount, the maximum relief encountered
would be only 100 meters.  If the area contains other bottom features of this
magnitude and shape ("background noise"), unique identification of this feature
as a seamount from this profile would be impossible.

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**(A)**

**(B)**

**(C)**
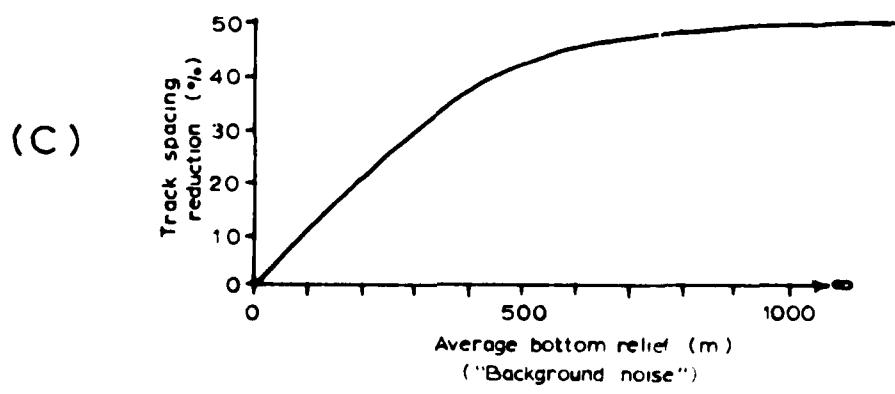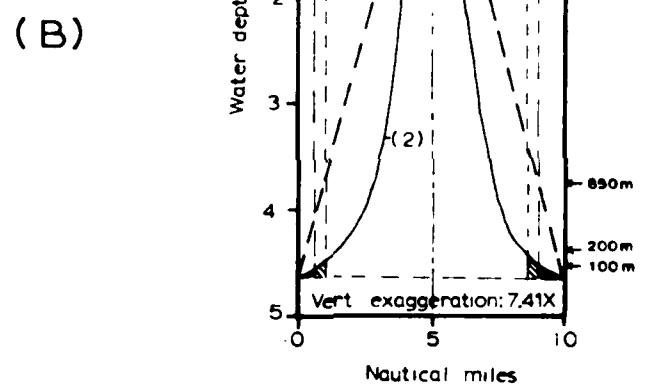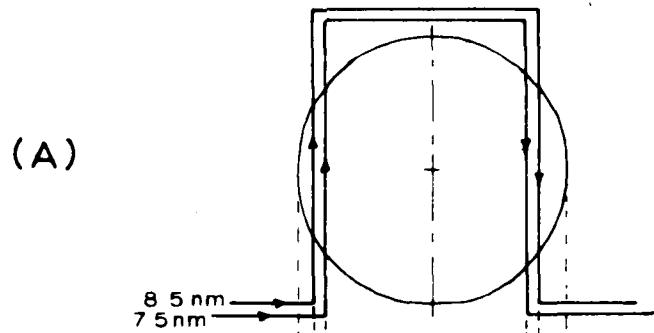
Figure 9. An example of survey track spacing reduction that may be required due to ambient bottom relief ("background noise").

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By reducing the track spacing to 7.5 nm (12%), and again using a minimum relief encounter configuration [figure 9 (A)], the maximum relief now encountered is 200 meters, 100 meters above the assumed background noise; and the feature would warrant further investigation.

In figure 9 (C) an attempt is made to relate background noise to required track spacing reductions. This figure is based on several assumptions, the most dubious being that all seamount gradients approximate those shown in figure 9 (B)-(2). If these limitations are recognized, however, the principles involved may serve as a useful tool in designing approximating track spacing reduction graphs in areas of various levels of background noise. One of the more obvious conclusions to be drawn from the figure is that track spacing need never be reduced more than 50% no matter how severe the background noise.

The conclusions reached in this study as to survey track orientation (normal to the sea-floor spreading direction) will be valid for any detection method, whether echo-sounding surveys or geophysical (shipboard or airborne gravity/magnetics) surveys. The track spacings given may require modification based upon the type of detection equipment used. For example: A wide-beam sonar array survey system may allow some increase in track spacing, depending on the characteristics of the equipment used, while an airborne gravity or magnetic survey may require a decrease in the given track spacing due to the limitations imposed by the decrease in the amplitude of these potential fields by the inverse square or cube (respectively) of the distance of the sensor from the source.

Finally, unless it can be determined by some independent means that there are no seamounts present in a given areas (that is, seamounts are not randomly distributed), the track spacings indicated here (or their modifications) will

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be required to ascertain the presence or absence of seamounts in the oceanic
areas indicated.

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Naval Oceanographic Office, Bathymetric Atlas of the North Atlantic Ocean (U), Spec. Pub. No. 1304, 130, 1975. CONFIDENTIAL

APPENDIX A

## NORTH ATLANTIC SEAMOUNT MORPHOLOGICAL PARAMETERS

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 00.6S | 006.3E | 1538 | 3000 | 1462 | 13 | 35 | 020 | 070 | -50 |
| 02.5S | 005.2E | 2512 | 4200 | 1688 | 7 | 15 | 030 | 070 | -40 |
| 03.6S | 003.5E | 3000 | 4800 | 1800 | 20 | 27 | 020 | 075 | -55 |
| 02.8S | 002.7E | 3038 | 4300 | 1262 | 20 | 30 | 050 | 075 | -25 |
| 02.4S | 002.5E | 2698 | 4500 | 1802 | 25 | 45 | 040 | 075 | -35 |
| 01.8S | 001.3E | 2342 | 4600 | 2258 | 15 | 15 | - | - | -- |
| 01.3S | 001.0E | 2625 | 4700 | 2075 | 20 | 27 | 035 | 070 | -35 |
| 00.3S | 001.7E | 2486 | 4600 | 2114 | 10 | 20 | 050 | 070 | -20 |
| 01.3N | 002.4E | 2775 | 4500 | 1725 | 10 | 20 | 030 | 070 | -40 |
| * | * | 2269 | 4400 | 2131 | 15 | 15 | - | - | -- |
| * | * | 1078 | 4000 | 2922 | 18 | 25 | 090 | 085 | 5 |
| * | * | 37 | 3800 | 3763 | 18 | 30 | 095 | 085 | 10 |
| * | * | 37 | 3700 | 3663 | 15 | 35 | 160 | 085 | 75 |
| * | * | 1528 | 4500 | 2972 | 22 | 22 | - | - | -- |
| * | * | 47 | 3300 | 3253 | 15 | 35 | 080 | 085 | -5 |
| * | * | 112 | 3100 | 2988 | 15 | 30 | 090 | 085 | 5 |
| * | * | 56 | 3700 | 3644 | 20 | 20 | - | - | -- |
| * | * | 49 | 3700 | 3651 | 15 | 20 | 140 | 085 | 55 |
| * | * | 56 | 3800 | 3744 | 22 | 30 | 050 | 085 | -35 |
| 02.9N | 040.5W | 1706 | 4500 | 2794 | 18 | 18 | - | - | -- |
| 01.3N | 040.9W | 2531 | 4300 | 1769 | 12 | 33 | 090 | 095 | -5 |
| 04.9N | 027.6W | 1222 | 4100 | 2878 | 12 | 33 | 090 | 085 | 5 |
| 06.1N | 024.9W | 1462 | 4300 | 2838 | 20 | 27 | 045 | 085 | -40 |
| 06.3N | 022.7W | 1320 | 3900 | 2580 | 17 | 25 | 100 | 085 | 15 |
| 06.9N | 021.9W | 1140 | 3400 | 2260 | 33 | 40 | 085 | 085 | 0 |
| 07.3N | 022.2W | 2325 | 4100 | 1775 | 21 | 40 | 070 | 085 | -5 |
| 07.9N | 021.9W | 1359 | 4100 | 2741 | 18 | 35 | 065 | 085 | -20 |
| 08.4N | 020.7W | 534 | 4100 | 3566 | 12 | 15 | 100 | 085 | 15 |
| 07.3N | 021.4W | 1940 | 3700 | 1760 | 14 | 14 | - | - | -- |
| 08.4N | 021.3W | 2051 | 4200 | 2149 | 13 | 13 | - | - | -- |

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APPENDIX A (Cont'd.)

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 08.4N | 020.7W | 2656 | 4100 | 1444 | 8 | 8 | - | - | -- |
| 08.8N | 020.1W | 1188 | 4100 | 2912 | 15 | 22 | 010 | 085 | -75 |
| 05.6N | 033.0W | 1905 | 3400 | 1495 | 15 | 15 | - | - | -- |
| 08.6N | 042.9W | 3187 | 4900 | 1713 | 20 | 30 | 090 | 095 | -5 |
| 15.3N | 021.9W | 488 | 4000 | 3512 | 20 | 23 | 010 | 110 | -100 |
| 10.5N | 024.2W | 3938 | 5300 | 1362 | 25 | 25 | - | - | -- |
| * | * | 2192 | 4000 | 1808 | 27 | 27 | - | - | -- |
| * | * | 3113 | 5000 | 1887 | 12 | 20 | 085 | 105 | -20 |
| * | * | 1275 | 4700 | 3425 | 20 | 20 | - | - | -- |
| * | * | 2810 | 5100 | 2290 | 18 | 22 | 055 | 105 | -50 |
| * | * | 994 | 4100 | 3106 | 20 | 27 | 160 | 115 | 45 |
| * | * | 1511 | 4100 | 2589 | 20 | 32 | 010 | 110 | -100 |
| * | * | 979 | 4000 | 3021 | 35 | 50 | 140 | 105 | 35 |
| * | * | 169 | 4100 | 3931 | 25 | 35 | 075 | 105 | -30 |
| * | * | 671 | 4200 | 3529 | 18 | 18 | - | - | -- |
| 33.5N | 057.0W | 806 | 3500 | 2694 | 12 | 23 | 100 | 065 | 15 |
| 34.4N | 052.5W | 2531 | 5200 | 2669 | 25 | 30 | 145 | 120 | 25 |
| * | * | 1968 | 5400 | 3432 | 23 | 23 | 125 | 125 | 0 |
| * | * | 1894 | 4700 | 2806 | 20 | 25 | 150 | 130 | 20 |
| * | * | 2343 | 4400 | 2057 | 12 | 20 | 155 | 130 | 25 |
| * | * | 1479 | 4200 | 2721 | 13 | 13 | - | - | -- |
| * | * | 1650 | 5300 | 3650 | 25 | 25 | - | - | -- |
| * | * | 1269 | 5100 | 3831 | 25 | 25 | - | - | -- |
| * | * | 2010 | 5100 | 3090 | 13 | 25 | 035 | 135 | -100 |
| * | * | 1471 | 4700 | 3229 | 22 | 22 | - | - | -- |
| * | * | 2193 | 5100 | 2907 | 15 | 15 | - | - | -- |
| * | * | 2531 | 5200 | 2669 | 13 | 13 | - | - | -- |
| * | * | 619 | 3000 | 2381 | 15 | 15 | - | - | -- |
| * | * | 1127 | 3200 | 2073 | 11 | 11 | - | - | -- |
| 41.1N | 052.7W | 3827 | 5100 | 1273 | 8 | 14 | 130 | 095 | 45 |
| * | * | 2999 | 4600 | 1601 | 9 | 25 | 060 | 085 | -25 |
| 47.7N | 041.6W | 2548 | 4400 | 1852 | 15 | 15 | - | - | -- |

APPENDIX A (Cont'd.)

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 08.4N | 020.7W | 2656 | 4100 | 1444 | 8 | 8 | - | - | -- |
| 08.8N | 020.1W | 1188 | 4100 | 2912 | 15 | 22 | 010 | 085 | -75 |
| 05.6N | 033.0W | 1905 | 3400 | 1495 | 15 | 15 | - | - | -- |
| 08.6N | 042.9W | 3187 | 4900 | 1713 | 20 | 30 | 090 | 095 | -5 |
| 15.3N | 021.9W | 488 | 4000 | 3512 | 20 | 23 | 010 | 110 | -100 |
| 10.5N | 024.2W | 3938 | 5300 | 1362 | 25 | 25 | - | - | -- |
| * | * | 2192 | 4000 | 1808 | 27 | 27 | - | - | -- |
| * | * | 3113 | 5000 | 1887 | 27 | 20 | 085 | 105 | -20 |
| * | * | 1275 | 4700 | 3425 | 20 | 20 | - | - | -- |
| * | * | 2810 | 5100 | 2290 | 18 | 22 | 055 | 105 | -50 |

* Only UNCLASSIFIED geographic locations listed.

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APPENDIX B

## NORTH PACIFIC SEAMOUNT MORPHOLOGICAL PARAMETERS

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 03.3N | 090.8W | 176 | 2400 | 2224 | 15 | 20 | 115 | 180 | -65 |
| 10.0N | 108.8W | 93 | 3500 | 3407 | 18 | 25 | 090 | 080 | 10 |
| 08.5N | 107.0W | 2000 | 3500 | 1500 | 17 | 31 | 150 | 080 | 70 |
| 06.0N | 104.8W | 1700 | 3500 | 1800 | 13 | 25 | 095 | 080 | |
| 14.3N | 107.1W | 1611 | 3500 | 1889 | 20 | 30 | 095 | 080 | 15 |
| 14.1N | 108.7W | 2518 | 3900 | 1382 | 12 | 50 | 085 | 090 | -5 |
| 12.9N | 103.5W | 1630 | 3100 | 1470 | 13 | 30 | 035 | 080 | -45 |
| 13.4N | 102.6W | 1600 | 3100 | 1500 | 13 | 13 | - | - | -- |
| 18.5 | 109.6W | 2260 | 3200 | 940 | 15 | 15 | - | - | -- |
| 21.6N | 108.4W | 1593 | 2800 | 1207 | 10 | 12 | 020 | 105 | -85 |
| 19.6N | 108.1W | 1593 | 3100 | 1507 | 12 | 27 | 070 | 100 | -30 |
| 06.9N | 111.1W | 815 | 3900 | 3085 | 16 | 20 | 025 | 080 | -55 |
| 06.4N | 111.1W | 824 | 3700 | 2876 | 25 | 45 | 070 | 090 | -20 |
| 16.9N | 117.5W | 28 | 3500 | 3472 | 17 | 23 | 100 | 100 | 0 |
| 13.5N | 119.9W | 524 | 4500 | 3976 | 21 | 33 | 090 | 080 | 10 |
| 16.6N | 114.8W | 552 | 3700 | 3148 | 11 | 11 | - | - | -- |
| 10.5N | 115.1W | 1185 | 4200 | 3015 | 19 | 19 | - | - | -- |
| 10.1N | 111.5W | 756 | 3500 | 2744 | 15 | 35 | 080 | 080 | 0 |
| 16.2N | 111.6W | 639 | 2800 | 2161 | 15 | 25 | 140 | 100 | 40 |
| 15.2N | 111.3W | 1574 | 3300 | 1726 | 18 | 32 | 060 | 095 | -35 |
| 15.4N | 110.9W | 417 | 3300 | 2883 | 22 | 27 | 070 | 095 | -25 |
| 13.3N | 110.5W | 1445 | 3700 | 2225 | 15 | 50 | 150 | 090 | 60 |
| 21.0N | 119.3W | 1491 | 3900 | 2409 | 12 | 12 | - | - | -- |
| 20.6N | 116.7W | 1689 | 3900 | 2211 | 13 | 13 | - | - | -- |
| 18.2N | 111.9W | 1565 | 3300 | 1735 | 10 | 40 | 070 | 100 | -30 |
| 25.3N | 119.6W | 393 | 4000 | 3607 | 18 | 20 | 040 | 080 | -40 |
| 27.7N | 119.3W | 1018 | 3900 | 2882 | 18 | 26 | 040 | 080 | -40 |
| 24.6N | 117.1W | 704 | 3800 | 3096 | 13 | 15 | 010 | 075 | -65 |

APPENDIX B (Cont'd.)

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 24.9N | 115.9W | 111 | 3700 | 3589 | 23 | 40 | 055 | 075 | -20 |
| 26.2N | 115.0W | 704 | 3300 | 2596 | 18 | 25 | 120 | 080 | 40 |
| 14.6N | 124.3W | 2519 | 4300 | 1781 | 12 | 16 | 130 | 080 | 50 |
| 22.6N | 127.5W | 2160 | 4300 | 2140 | 22 | 22 | - | - | - |
| 20.4N | 121.5W | 1361 | 4300 | 2939 | 16 | 16 | - | - | - |
| 17.8N | 123.8W | 496 | 4200 | 3704 | 16 | 16 | - | - | - |
| 17.7N | 124.1W | 695 | 4200 | 3505 | 16 | 16 | - | - | - |
| 20.3N | 121.5W | 1361 | 4100 | 2739 | 16 | 16 | - | - | - |
| 25.0N | 121.7W | 704 | 4100 | 3396 | 27 | 35 | 000 | 085 | -85 |
| 23.1N | 125.1W | 648 | 4100 | 3452 | 12 | 12 | - | - | - |
| 27.1N | 123.0W | 2037 | 4100 | 2063 | 14 | 25 | 040 | 080 | -40 |
| 27.5N | 122.8W | 1837 | 4100 | 2263 | 16 | 27 | 065 | 080 | -15 |
| 32.3N | 127.8W | 445 | 4300 | 3855 | 23 | 28 | 080 | 080 | 0 |
| 32.2N | 127.3W | 1141 | 4300 | 3159 | 17 | 17 | - | - | - |
| 32.1N | 126.9W | 865 | 4300 | 3435 | 20 | 20 | - | - | - |
| 31.8N | 126.3W | 1148 | 4300 | 3152 | 15 | 17 | 100 | 090 | 10 |
| 30.5N | 122.7W | 556 | 4100 | 3544 | 16 | 20 | 060 | 080 | -20 |
| 30.6N | 123.2W | 1282 | 4100 | 2818 | 17 | 17 | - | - | - |
| 33.1N | 121.0W | 559 | 3600 | 3041 | 18 | 27 | 020 | 080 | -60 |
| 40.9N | 128.9W | 1190 | 3200 | 2010 | 9 | 12 | 030 | 100 | -70 |
| 00.0N | 134.8W | 1524 | 4200 | 2676 | 31 | 35 | 010 | 070 | -60 |
| 22.5N | 131.1W | 1333 | 4600 | 3267 | 13 | 20 | 105 | 090 | 15 |
| 28.9N | 135.8W | 1478 | 4300 | 2822 | 15 | 22 | 105 | 85 | 20 |
| 32.8N | 132.5W | 417 | 4300 | 3833 | 20 | 30 | 120 | 85 | 35 |
| 39.0N | 131.1W | 1945 | 4300 | 2355 | 13 | 22 | 150 | 85 | 65 |
| 28.0N | 137.5E | 1094 | 4300 | 3206 | 15 | 25 | 140 | 155 | -15 |
| 24.5N | 135.2E | 1483 | 4600 | 3117 | 16 | 22 | 040 | 155 | -115 |
| 19.1N | 133.7E | 2222 | 5700 | 3478 | 12 | 18 | 145 | 150 | -5 |
| 04.7N | 130.8E | 787 | 4500 | 3713 | 15 | 15 | - | - | - |
| 40.6N | 146.9E | 1346 | 5200 | 3854 | 16 | 20 | 165 | 165 | 0 |
| 40.9N | 144.9E | 3543 | 6300 | 2757 | 15 | 20 | 085 | 165 | -80 |
| 35.8N | 144.3E | 1418 | 5700 | 4282 | 22 | 26 | 035 | 155 | -120 |

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APPENDIX B (Cont'd.)

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 32.8N | 148.4E | 1422 | 5800 | 4378 | 25 | 25 | - | - | -- |
| 23.8N | 148.8E | 1000 | 5700 | 4700 | 28 | 32 | 045 | 050 | -5 |
| 27.3N | 145.2E | 76 | 5000 | 4924 | 20 | 27 | 005 | 150 | -145 |
| 12.5N | 149.6E | 2593 | 5600 | 3007 | 17 | 25 | 035 | 045 | -10 |
| 12.2N | 146.6E | 926 | 5600 | 4674 | 25 | 28 | 145 | ? | ? |
| 05.5N | 149.2E | 9 | 3900 | 3891 | 20 | 40 | 100 | ? | ? |
| 29.4N | 153.5E | 1333 | 5600 | 4267 | 30 | 40 | 120 | 155 | -35 |
| 31.6N | 151.2E | 1393 | 5600 | 4207 | 25 | 30 | 130 | 155 | -25 |
| 26.5N | 152.1E | 2037 | 5600 | 3563 | 22 | 36 | 045 | 045 | 0 |
| 18.6N | 158.2E | 1482 | 5600 | 4118 | 20 | 35 | 050 | 045 | 5 |
| 21.3N | 153.2E | 1074 | 5600 | 4526 | 27 | 40 | 055 | 045 | 10 |
| 19.2N | 152.8E | 1296 | 5400 | 4134 | 24 | 35 | 050 | 045 | 10 |
| 15.7N | 152.1E | 1250 | 5600 | 4350 | 28 | 40 | 155 | ? | ? |
| 11.2N | 159.3E | 1852 | 5400 | 3548 | 22 | 33 | 150 | ? | ? |
| 14.4N | 155.8E | 1574 | 5700 | 4126 | 23 | 40 | 025 | ? | ? |
| 07.0N | 156.9E | 2130 | 4500 | 2370 | 15 | 15 | - | - | -- |
| 39.8N | 166.5E | 2654 | 5400 | 2746 | 22 | 22 | - | - | -- |
| 27.9N | 168.9E | 1518 | 5700 | 4182 | 23 | 27 | 050 | 045 | 5 |
| 24.9N | 165.6E | 3574 | 5700 | 2126 | 17 | 33 | 030 | 050 | -20 |
| 23.6N | 168.8E | 2871 | 5700 | 2829 | 15 | 23 | 050 | 060 | -10 |
| 19.4N | 166.0E | 1120 | 5300 | 4180 | 22 | 25 | 085 | 050 | 35 |
| 21.2N | 166.5E | 1185 | 5000 | 3815 | 35 | 35 | - | - | -- |
| 19.8N | 164.9E | 1409 | 5200 | 3791 | 40 | 55 | 165 | 050 | 115 |
| 07.8N | 163.1E | 1203 | 4900 | 3697 | 35 | 40 | 015 | ? | ? |
| 08.3N | 163.1E | 1111 | 5000 | 3884 | 35 | 45 | 165 | ? | ? |
| 32.6N | 178.8E | 1667 | 5000 | 3333 | 15 | 20 | 015 | 050 | -35 |
| 34.0N | 178.1E | 118 | 2900 | 2782 | 11 | 11 | - | - | -- |
| 29.2N | 175.7E | 1852 | 5100 | 3248 | 25 | 25 | - | - | -- |
| 28.2N | 178.0E | 1981 | 5000 | 3019 | 13 | 13 | - | - | -- |
| 22.1N | 171.6E | 1281 | 5400 | 4119 | 23 | 27 | 140 | 040 | 100 |
| 22.7N | 176.5E | 1685 | 5400 | 3715 | 28 | 39 | 050 | 050 | 0 |
| 13.1N | 179.3E | 2130 | 5600 | 3470 | 25 | 40 | 065 | 060 | 5 |

APPENDIX B (Cont'd.)

| Lat. (deg.) | Long. (deg.) | Depth to Top (m) | Bottom Depth (m) | Delta Depth (m) | Short Axis (nm) | Long Axis (nm) | Long Axis Azm. (deg.) | Sea-Floor Spreading Azm. (deg.) | Delta Azm. (deg.) |
|---|---|---|---|---|---|---|---|---|---|
| 13.4N | 179.9E | 2222 | 5600 | 3378 | 14 | 14 | - | - | -- |
| 05.9N | 173.3E | 15 | 4600 | 4585 | 10 | 10 | - | - | -- |
| 29.8N | 174.0W | 648 | 5300 | 4652 | 25 | 25 | - | - | -- |
| 30.7N | 173.1W | 1074 | 5200 | 4126 | 17 | 30 | 160 | 070 | 90 |
| 28.0N | 171.1W | 604 | 4600 | 3996 | 20 | 45 | 135 | 070 | 65 |
| 28.6N | 176.7W | 65 | 4500 | 4535 | 30 | 38 | 155 | 070 | 85 |
| 13.5N | 173.4W | 852 | 5500 | 4648 | 35 | 45 | 165 | 025 | 140 |
| 01.0 | 179.4W | 1296 | 5300 | 4004 | 20 | 45 | 080 | 170 | -90 |

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